SYNOPSIS

Synthesis and Development of Nano-polymer Based Composite Materials for Device Application

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by

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1. Introduction

Researchers were drawn towards nano metal oxides[1] and sulfides[2] because of their promising qualities of high optical absorbance and direct band gap. Furthermore, due to their electrical and thermal insulating qualities, stable polymers such as (PVA, PVP, PMMA, PVDF, etc.) have gained relevance in a variety of applications such as electronic, packaging, insulation, and so on. When these two materials are combined, their physical and chemical properties change, and an advanced material with intriguing physical and chemical properties may arise.

The optical and electrical properties of the composite enhances due to the incorporation of nano-particles into a polymer matrix[3]. As example; polyvinyl alcohol (PVA) with good water solubility, biocompatibility, and excellent film-forming ability. Mengru Zhu et al. showed enhancement in the UV photo-detection ability of PVA-Carbon nano-dot composite material[4]. Morget Martin et al. reported Optical, phonon properties of ZnO–PVA, ZnO–GO–PVA nano-composite free standing polymer films for UV sensing[5], S. S. Mousavi et al. reported fast response ZnO/PVA nano-composite-based photodiodes modified by graphene quantum dots[6], and many more such examples are available, which utilized nano-polymer composite materials for antistatic materials, rechargeable batteries, photo-sensors, pressure sensors, and chemical sensors, electromagnetic shielding, organic solar cells, optical waveguides, etc.[7].

This work is based on the above concept of utilization of nano (metal or metal oxide or metal sulfide) –polymer nano-composite materials for viable electronic application like photo-sensor, pressure-sensor[3], gas sensor[4], etc.

2. Review of Literature and Development in the Subject:

Mixing of metal oxide /sulfide nano-particles in polymer via stirring or spinning are traditionally studied method to fabricate nano-composite materials for its applications in optoelectronics, sensors, etc. devices. For example,

> Muhammad Aslam, et.al has reported synthesis of a fexible, strong and optically tunable nano-CuO-loaded poly(vinylalcohol) composite films by means of solution casting method. The nano-CuO intercession has modified the desirable properties of the PVA matrix[7].

Mengru Zhu, et.al studied that carbon nanodots (CNDs) mixed with PVA film show excellent solar-blind ultraviolet (UV) photodetector, where the responsivity and external quantum efciency reached 267.1 mA/W and 158%, respectively[4].

B. Hanna, et.al reported the fabrication and characterization of visible-blind UV photodetectors using thin films of polymer/zinc oxide (ZnO) nanocomposites[8].

S. S. Mousavi, et.al reported polymer-based photodetectors using Poly (vinyl alcohol) as the host polymer and ZnO@graphene quantum dots utilized as the filler of the polymer matrix[6].

Y. Yoon et al. reported the construction of flexible/wearable sensors based on metal-oxide nano-materials (MONs), which have gained considerable interest due to their tunable band gap, low cost, large specific area, and ease of manufacturing[1].

Wen-Tao Guo et al. reported recent progress on the polymer composite-based flexible pressure sensor using the parameters sensitivity, linear response range, detection limit, response speed, and reliability[3].

3. Objectives of Research/proposed Hypothesis

This work investigates the photo-conducting properties of nano metal oxide/sulfide and polymer composite materials synthesized using sol-gel method and spin coating method and possible development of highly sensitive and fast responsive optoelectronic device as well as mechanical device using the deposited film. To achieve the above mention objective this work is made of specific aims;

a. To synthesize nano-composites (PVA-Ag, PVA-PANI, PVA-SnO_2, PVA-CdS, etc.) using sol-gel method
b. To characterize synthesized nano-composites using XRD, UV–Vis spectroscopy, Raman spectroscopy, TGA-DTA, SEM-EDS, XPS, etc.
c. To study the photo–conducting or pressure or gas sensor properties of thin film devices using dedicated setup.

d. To probe the electronic structure of the film using optical and X-ray photoelectron spectroscopy and understanding the role of its intrinsic properties on photo-conductivity
e. To propose effective photo-detector or pressure or gas sensor device based on the results and material properties.

4. Methodology to be adopted

This work includes synthesis of nano metal/metal oxide/metal sulfide particles and polymer based composite materials for its viable application in development of optoelectronic or pressure sensor device application. This work designed to run on three stages;

Stage-1: Synthesis of nano metal/metal oxide/metal sulfide particles and its composites: The motivation behind this stage is to synthesize mono dispersed metal or metal oxide or metal sulfide nano-particles using sol-gel method and to synthesize its composite with polymers. Also to study its structural, morphological and optical properties using various characterization techniques.

Stage 2: Device property measurements: In this stage, spin coating method is used to deposit a film of the synthesized composite material on glass substrate using spin coating technique. Phot-detector or pressure or gas sensor devices were prepared using these films and their device characteristics were tested in laboratory.

Stage 3: Development of a viable optoelectronic or pressure or gas sensor device based on the obtained results: The results of the investigation will be used to fabricate viable photo-detector or pressure or gas sensor based on composite material.

5. Importance of study/ Society application:

In recent years, extensive research is going on in the area of synthesis of advanced functional material owing to its promising applications in the field of opto-electronic and pressure sensor devices[1-5]. Recent reports have shown that nano metal oxide or sulfide and polymer composite materials show excellent photo-conducting or pressure sensing properties[1-5]. These thin films have been prepared by various physical and chemical methods. All these techniques do have several merits and limitations. Among these techniques, the spin coating or spray pyrolysis method gives higher coating area, high superior homogeneity, high purity, better micro structural control and narrow thickness variation as compared with those prepared by

physical methods. The spin coating or spray pyrolysis method have additional advantages like its simplicity, cost effectiveness and its ability to deposit uniform films, moreover, its reproducibility in a relatively shorter processing time at lower temperatures is remarkable. Current electronic industries need a method, which is low-cost, and large-scale integration.

This work focuses on the connectivity between the nano metal or metal oxide or metal sulfide and polymer composite platforms based on photo-conducting or pressure sensing materials; emphasizing synergetic integration with potential for novel effects exclusive to the hybrid concept.

6. Proposed work Plan/ Formulation and Structure of Study: Year-wise Plan of work and targets to be achieved

First year:

a. Initiate synthesis of nano-composite thin film (PVA-Ag, PVA-PANI, PVA-SnO_2, PVA-CdS, etc.) on flexible substrate using dip coating/spin coating/spray pyrolysis.
b. Study the effect of time/cycle of deposition, temperature, and flexible substrate on film morphology.
c. Initiate testing of device properties of these film fabricated on a flexible substrate.

Second year:

a. Optimize deposition technique for the synthesis of functional nano-composite thin film on various flexible substrates.
b. Perform extensive characterizations including UV-Vis, XRD, AFM, TGA, SEM-EDS, and XPS to know the structural, morphological, optical, and electronic properties of nano-composite thin film.
c. Initiate making device structure by putting metal contacts.

Third year:

a. Perform real-time device (Pressure sensor, gas sensor, photodetector, etc.) measurement on the fabricated device.
b. Estimate the device parameters like responsivity, detectivity, sensitivity, response time, efficiency, noise equivalent power, gain, etc.

Fourth year:

a. Initial testing of flexible device properties of functional nano-composite thin film.
b. Start publishing research papers

Fifth year:

a. Review the status of progress during the first two years and take appropriate steps towards the most effective utilization of the knowledge, facilities, and experience during the remaining duration**.**
b. Continue to analyze the data obtained and proceed with publications /patenting as appropriate.
c. Prepare thesis for submission**.**

References :-

[1] Y. Yoon, P.L. Truong, D. Lee, S.H. Ko, Metal-Oxide Nanomaterials Synthesis and Applications in Flexible and Wearable Sensors, ACS Nanosci. Au. 2 (2022) 64–92. https://doi.org/10.1021/acsnanoscienceau.1c00029.

[2] K. Sun, S. Song, A. Kumar, Z. Shang, X. Duan, S. Wang, S. Tian, J. Tang, D. Zhou, X. Sun, Synthesis of Nanosized Metal Sulfides Using Elemental Sulfur in Formamide: Implications for Energy Conversion and Optical Scenarios, ACS Appl. Nano Mater. 4 (2021) 2357–2364. https://doi.org/10.1021/acsanm.1c00080.

[3] W.-T. Guo, X.-G. Tang, Z. Tang, Q.-J. Sun, Recent Advances in Polymer Composites for Flexible Pressure Sensors, Polymers (Basel). 15 (2023). https://doi.org/10.3390/polym15092176.

[4] M. Zhu, Z. Zhao, Y. Fang, C. Fang, Z. Weng, W. Lei, S. Bin Shafie, M.N. Mohtar, An enhanced solar-blind ultraviolet photodetector based on polyvinyl alcohol/carbon nanodots film, Appl. Phys. A Mater. Sci. Process. 127 (2021). https://doi.org/10.1007/s00339-021-04793-2.

[5] M. Martin, N. Prasad, M.M. Sivalingam, D. Sastikumar, B. Karthikeyan, Optical, phonon properties of ZnO–PVA, ZnO–GO–PVA nanocomposite free standing polymer films for UV sensing, J. Mater. Sci. Mater. Electron. 29 (2018) 365–373. https://doi.org/10.1007/s10854-017-7925-z.

[6] S.S. Mousavi, B. Sajad, M.H. Majlesara, Fast response ZnO/PVA nanocomposite-based photodiodes modified by graphene quantum dots, Mater. Des. 162 (2019) 249–255. https://doi.org/10.1016/j.matdes.2018.11.037.

[7] M. Aslam, M. Ali, K. Zulfiqar, A. Raza, Fabrication of nano - CuO - loaded PVA composite films with enhanced optomechanical properties, Polym. Bull. 78 (2021) 1551–1571. https://doi.org/10.1007/s00289-020-03173-9.

[8] B. Hanna, L.R. Pillai, K. Rajeev, K.P. Surendran, K.N.N. Unni, Visible-blind UV photodetectors using a polymer/ZnO nanocomposite thin film, Sensors Actuators A Phys. 338 (2022) 113495. https://doi.org/https://doi.org/10.1016/j.sna.2022.113495.

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